

Lean and Heavy Women May Not Use Energy from Alcohol with Equal Efficiency^{1,2}

BEVERLY A. CLEVIDENCE,^{*3} PHILIP R. TAYLOR,[†] WILLIAM S. CAMPBELL[†] AND JOSEPH T. JUDD^{*}

^{*}Diet and Human Performance Laboratory, Beltsville Human Nutrition Research Center, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, MD 20705-2350 and [†]Cancer Prevention Studies Branch, Division of Cancer Prevention and Control, National Cancer Institute, Department of Health and Human Services, Bethesda, MD 20892

ABSTRACT To assess whether energy from alcohol is efficiently utilized to maintain body mass, we examined changes in energy intake of young women when they drank alcohol. The women ate controlled diets typical of the American diet with regard to macronutrients. Body weights were controlled to within 1 kg of entry level weights. The subjects were given alcohol (30 g/d) and no alcohol treatments for 3 mo each in a crossover design. The treatments were isoenergetic; for the no alcohol treatment alcohol energy was replaced with energy from carbohydrate. The average change in energy intake associated with the alcohol treatment was negligible when all subjects were considered collectively. There was, however, a divergence in response between lean and heavy subjects. Fifteen women required, on average, an additional 886 ± 147 (mean \pm SEM) kJ/d to maintain body weight during the alcohol treatment, and these women were leaner (body mass index 22.6 ± 0.8 kg/m² vs. 25.2 ± 1.0 , $P < 0.05$) than the 22 women who required, on average, 559 ± 139 fewer kJ/d when on the alcohol treatment. This study suggests that all subjects do not use energy from alcohol with equal efficiency. *J. Nutr.* 125: 2536-2540, 1995.

INDEXING KEY WORDS:

- alcohol • energy • body mass index
- humans

Energy from alcohol may not be efficiently utilized to maintain body weight (Colditz et al. 1991, Fisher and Gordon 1985, Gruchow et al. 1985, Jones et al. 1982). As might be expected, drinkers consume more energy than nondrinkers; but, in contrast to common wisdom, they are not more likely to be overweight even though exercise habits are similar (Colditz et al. 1991, Gruchow et al. 1985, Jones et al. 1982). Male drinkers and nondrinkers are similar in body weight, whereas females who drink moderately are, on average, leaner than those who are nondrinkers (Colditz

et al. 1991, Fisher and Gordon 1985, Jones et al. 1982, Williamson et al. 1987).

These epidemiological studies have relied on 24-h recall or food frequency questionnaires to assess alcohol and energy intakes. However, these observations are supported by experimental studies in which high levels of alcohol were administered to subjects in metabolic wards. For example, addition of 24% of energy as alcohol to a basal diet did not cause weight gain in lean men (Crouse and Grundy 1984), and isoenergetic substitution of alcohol for carbohydrate, up to 50% of energy, failed to maintain body weight in previously weight-stabilized subjects (Lieber 1991, Pirola and Lieber 1972).

We conducted a controlled diet study of young women to assess estrogen and lipoprotein response to moderate levels of alcohol (Clevidence et al. 1995, Reichman et al. 1993). This paper uses data from that study to examine the hypothesis that there was no significant shift in energy intake in weight-stable women when they changed between the alcohol and the no alcohol treatments.

SUBJECTS AND METHODS

Subjects

Subjects were healthy premenopausal women age 21-40 y (Table 1). Eligibility criteria for the study,

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³ To whom correspondence should be addressed: Diet and Human Performance Laboratory, Bldg 308 Rm 116, BARC-East, 10300 Baltimore Avenue, Beltsville, MD 20705-2350.

TABLE 1

Baseline characteristics of 37 premenopausal women¹

Age, y	30 ± 1
Drinks per week ²	1.6 ± 0.2
Height, cm	164 ± 2
Weight, kg	65 ± 2
Body mass index, kg/m ²	24.2 ± 0.7

¹ Values are means ± SEM.² From subjects' self-administered medical history questionnaire. One drink was defined as 360 mL of beer, 120 mL of wine or 30 mL of liquor.

which have been described in detail (Clevidence et al. 1995), required that the women were as follows: 1) social drinkers with no family history of alcohol abuse; 2) nonsmokers; 3) not using over-the-counter or prescription medications including oral contraceptives; and 4) within 80–130% of ideal body weight according to values in the 1983 Metropolitan Life Insurance table of desirable weights (Andres et al. 1985). All subjects passed screening tests to establish normal liver, kidney and thyroid function. Assessment of normal liver function included levels of serum glutamic-pyruvic transaminase (SPGT) and serum glutamic-oxaloacetic transaminase (SGOT). Drinking history of the women before entering the study, as determined from a self-administered questionnaire, ranged from one to eight drinks per week (mean ± SEM, 1.6 ± 0.2). A drink was defined as 360 mL of beer, 120 mL of wine or 30 mL of liquor. All procedures were approved by the Institutional Review Boards of the National Cancer Institute, National Institutes of Health and Georgetown University College of Medicine. Informed consent was obtained from all subjects in accordance with Institutional guidelines. Thirty-seven of the 42 women who started the study completed the two crossover phases; the 5 dropouts were eliminated from data analysis.

Subjects were paired by age and body mass index (BMI, weight [kg]/height [m]²) for assignment to treatment-order groups. Body weights were monitored each weekday before breakfast. Energy intake was adjusted, as needed, to maintain body weight within 1 kg. Body weights, change in body weight, energy intake and change in energy intake of each woman were averaged over 30 d at the end of each treatment period and compared between the alcohol and no alcohol treatments.

Study design and treatments

The diet study lasted for approximately 6 mo. Subjects started the controlled diets the same day, and each finished after completing her sixth complete menstrual cycle. The controlled diet met the RDA (National Research Council 1989) for known nutrients

and was typical of the American diet with regard to distribution of energy among macronutrients (carbohydrate or carbohydrate plus alcohol, 53%; protein, 14%; fat, 36%). Menus were prepared in 840-kJ increments by proportionally scaling each food item. A 14-d menu cycle was used to provide variety. Subjects ate breakfast and dinner meals under observation at the dietary facility, Beltsville Human Nutrition Research Center, Monday through Friday. Lunch, snacks and weekend meals were packed for off-site consumption. Subjects agreed to consume all of the food and drink and only the food and drink provided in the context of the study.

Alcohol or no alcohol treatments were administered in a crossover design with each treatment lasting for three consecutive menstrual cycles. For the alcohol treatment, subjects consumed 30 g of alcohol (~ 840 kJ) in a fruit juice vehicle each night just before bedtime. This is the equivalent of about two alcoholic beverage servings (drinks) per day. When subjects were on the no alcohol treatment, they consumed the fruit juice vehicle without alcohol and, to compensate for alcohol energy, an additional 840 kJ as carbohydrate from soft drinks.

Statistical analysis

For comparison of alcohol to no alcohol treatments, data were analyzed by two-tailed, paired *t* tests using the programs of the SAS Institute (SAS/STAT Version 5.18, SAS Institute, Cary, NC). An unpaired *t* test was used to compare BMI of subjects as stratified by energy intake during the period of alcohol consumption. Correlation coefficients were determined by the Pearson product-moment method. An α value of 0.05 was considered statistically significant (Snedecor and Cochran 1980). Values in the text are means ± SEM.

RESULTS

Subjects reported no adverse reactions to the alcohol treatment. Blood alcohol concentrations were not measured because of the late (bedtime) consumption of alcohol. Estimates of peak blood alcohol concentrations, based on BMI, sex of the subjects and length of the drinking period (Kapur 1992), ranged from 10 to 17 mmol/L (mean ± SEM, 13 ± 0.3). The percent of total energy from alcohol ranged from 8% for women consuming 11.76 MJ/d to 16% for those consuming 5.88 MJ/d. The mean values for energy intake and the percent of energy from alcohol were 8.15 MJ and 11%, respectively.

Changes in body weight between the alcohol and no alcohol treatments were negligible, as expected, because body weight was tightly controlled. This was true both when the 37 subjects were considered col-

TABLE 2

Changes in weight and energy intake of subjects who consumed more energy ($\Delta kJ > 0$) and those who consumed the same or less energy ($\Delta kJ \leq 0$) when on the alcohol rather than the no alcohol treatment^{1,2,3}

	All subjects	$\Delta kJ > 0$	$\Delta kJ \leq 0$
n	37	15	22
Age, y	30 ± 0.8	30 ± 1.5	31 ± 0.9
Body mass index, kg/m^2	24.2 ± 0.7	22.6 ± 0.8	25.2 ± 1.0
Δ weight (kg) (alcohol vs. no alcohol)	-0.05 ± 0.19	-0.04 ± 0.22	-0.05 ± 0.28
Δ kJ (alcohol vs. no alcohol)	25 ± 155	$886 \pm 147^*$	$-559 \pm 139^*$

¹ Values are means \pm SEM.

² To convert kJ to kcal, divide by 4.2.

³ Significant difference between alcohol and no alcohol treatments; * $P < 0.001$.

lectively and when the subjects were stratified into those who required more energy and those who required equal or lower energy to maintain body weight during the alcohol treatment (Table 2).

The average change in energy intake as a result of being on the alcohol rather than the no alcohol treatment was negligible (25 ± 155 kJ) when all subjects were considered collectively. However, the variability in response among individuals was large. Fifteen subjects required, on average, an additional 886 ± 147 kJ/d to maintain body weight during the alcohol treatment, and 22 subjects required an average of 559 ± 139 fewer kJ/d to maintain body weight during the alcohol treatment. The women who re-

quired additional energy were leaner than those who required less energy or no energy adjustment during the period of alcohol consumption (BMI of 22.6 ± 0.8 vs. 25.2 ± 1.0 , $P < 0.05$). The correlation between change in energy intake and BMI was significant ($r = -0.37$, $P = 0.02$).

Energy intakes of individuals are displayed in Figure 1 for both the alcohol and no alcohol treatment periods. Among the subjects who required more energy to maintain body weight during the alcohol treatment period, 13 of 15 had a BMI of < 25 ; 5 of 10 subjects who maintained weight with fewer kJ during the alcohol treatment had a BMI of > 25 . Similar results (not shown) were observed when energy intake for the

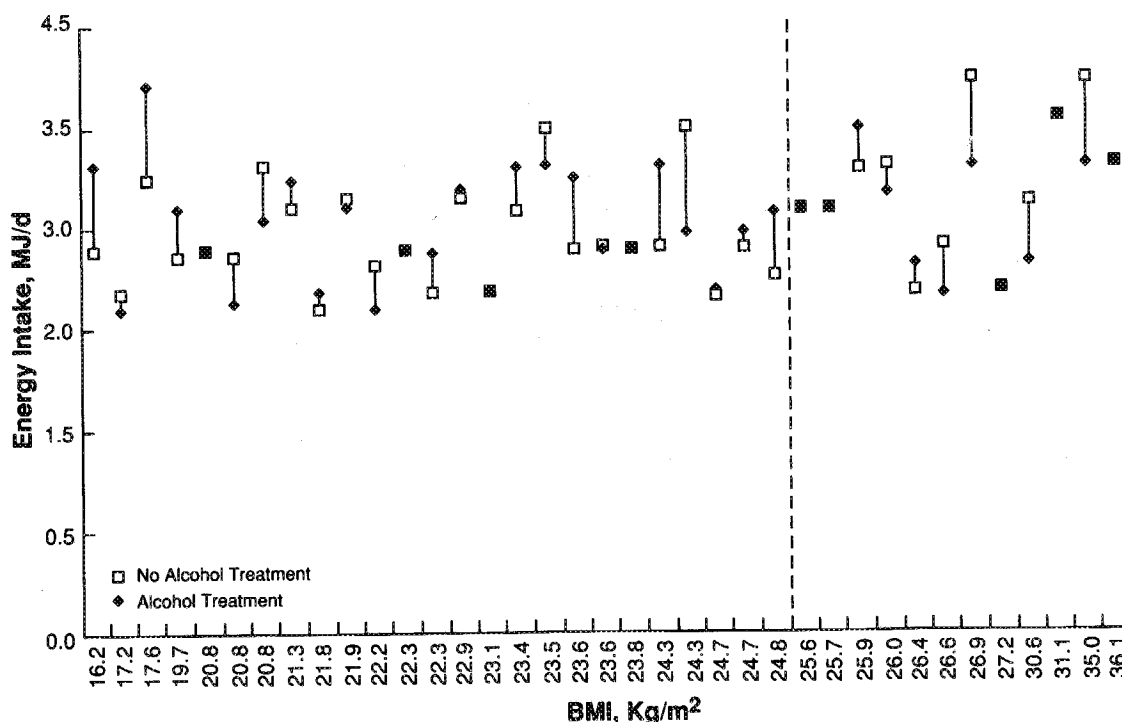


FIGURE 1 Energy intake of individual subjects during the alcohol and no alcohol treatment periods for subjects with the body mass index of $<$ and > 25 kg/m^2 . No change in energy level between treatments is indicated when the diamond fits completely within the square. BMI = body mass index.

two treatments was plotted against body weight rather than BMI.

The BMI/MJ, a measure of efficiency of energy use, varied greatly among individuals for the two treatment periods (Fig. 2). Among those subjects who used energy less efficiently during the alcohol treatment period, 13 of 15 subjects had a BMI of < 25 . In Figure 2 less efficient use of energy from alcohol for an individual is indicated when the height of the open symbol, which represents the no alcohol treatment, exceeds the height of the closed symbol, which represents the alcohol treatment. Conversely, 5 of the 10 subjects who used energy more efficiently during the alcohol treatment period had a BMI > 25 kg/m².

DISCUSSION

Alcohol provides 29.69 kJ/g as determined by bomb calorimetry and, as adjusted for 98% coefficient of digestibility, is estimated to provide 29.11 kJ of metabolizable energy per gram (U.S. Department of Agriculture 1976–1988). However, the question of whether alcohol-derived energy actually contributes to maintenance of body weight in accordance with this value is a point of controversy.

When viewed collectively, data from the 37 subjects support the position that energy from alcohol and car-

bohydrate are used with equal efficiency. However, a subset of subjects required more energy to maintain body weight when on the alcohol treatment. Subjects who required additional energy for weight maintenance were, on average, leaner as judged by BMI than those who required less energy or no energy adjustment for weight maintenance. Our findings parallel those of Crouse and Grundy (1984) who reported a similar effect of alcohol in lean and obese male subjects. Those men consumed a basal diet plus 24% of energy as alcohol (90 g) daily for 4 wk. In that study, the lean men did not gain weight with alcohol as added energy, whereas most of the obese subjects did.

There is presently no explanation of why alcohol would tend to promote inefficient utilization of energy in individuals with low BMI (lean subjects) and highly efficient utilization in those with higher BMI (heavier subjects). The BMI is, most likely, a surrogate for one or more specific variables that our study did not measure. The relation of energy utilization to BMI may be a function of body composition, and more specifically, energy stores.

In our study, all subjects received the same amount of alcohol, regardless of body weight. Alcohol represented, at the average energy intake of 8.15 MJ, 11% of total energy but ranged from 8% for women consuming the highest energy level (11.76 MJ) to 16% of energy for women consuming the lowest energy level (5.88 MJ). It could be argued that lean subjects failed

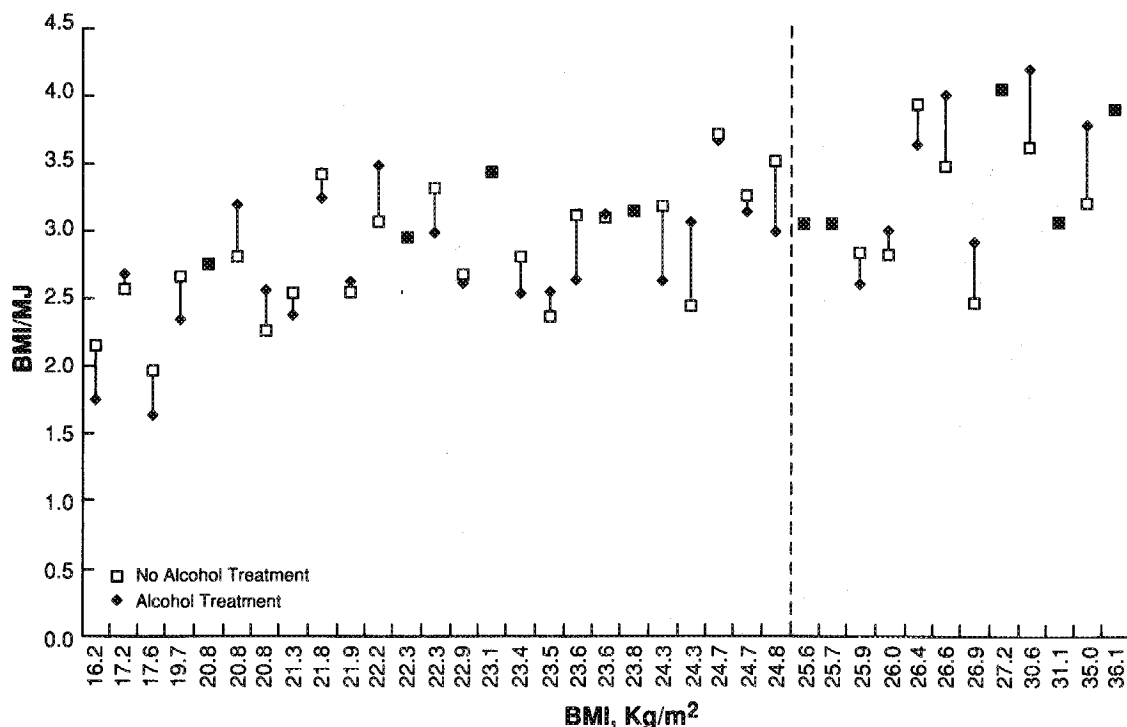


FIGURE 2 Efficiency of energy use by individuals with the body mass index of $<$ and > 25 kg/m² during alcohol or no alcohol treatment periods. No change in efficiency of alcohol use between treatments is indicated when the diamond fits completely within the square. Less efficient use of alcohol energy by an individual is indicated when the height of the open symbol exceeds that of the closed symbol. BMI = body mass index.

to use energy from alcohol efficiently because they received an effectively higher dose of alcohol. If so, this would differ from the effect on blood lipids of these subjects; the alcohol-induced response of plasma lipoprotein levels was not related to BMI (Clevidence et al. 1995). Alcohol may induce an increase in energy dissipation, and this increased energy output may be more likely to occur in lean subjects. Energy expenditure is increased when alcohol is added to a basal diet or isoenergetically substituted for food (Suter et al. 1992, Suter et al. 1994). Possible mechanisms for energy wastage have been reviewed (Lands and Zakhari 1991, Lieber 1994, Pirola and Lieber 1976). Most of these mechanisms explain inefficient use of energy from alcohol at high levels of alcohol intake. A distinctive feature of our study is the suggestion that energy from alcohol may be inefficiently utilized at levels of alcohol intake associated with social drinking.

The daily alcohol dose used in our study, 30 g, is equivalent to ~ 840 kJ. This is comparable with the average additional energy (886 kJ/d) intake of the 15 women who required an increase in energy intake to maintain weight during the period that alcohol was consumed. However, the alcohol-induced change in energy requirement varied greatly among the 15 women (range 59–1848 kJ). Five women required additional energy exceeding the energy value of the alcohol. Although this may be due to energy wastage of undetermined mechanism, these large changes in energy intake raise questions of compliance. To ensure safety of the subjects, we required that subjects consume the alcohol just before bedtime, and thus alcohol consumption was not observed by us. We also did not monitor physical activity patterns of the subjects. Thinner women, if more weight conscious, might occasionally fail to comply with complete consumption of the alcoholic beverage or they may have exercised more during the period of alcohol consumption. However, it is more difficult to rationalize why heavier women required less energy during the period when alcohol was consumed.

This study supports the concept that all individuals do not use energy from alcohol with equal efficiency, even at levels of alcohol intake equivalent to two drinks a day. These observations are from a study that was designed to carefully control body weight, but alcohol-induced changes in energy intake were not the primary focus of the research design. Further controlled diet studies that assess energy utilization by calorimetry are needed to assess the effect of alcohol on energy utilization.

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